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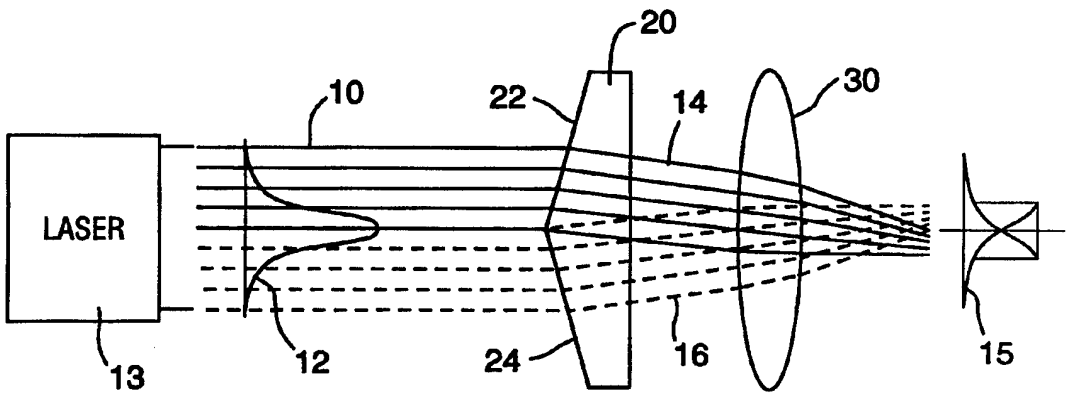

(57) Abstract

An optical apparatus is disclosed for reconfiguring a round laser beam having a gaussian-like intensity distribution into a square or rectangular beam having a uniform intensity distribution. A first optical element is used to divide the beam into two halves along a first axis. A second optical element is used to divide the beam in half along an axis perpendicular to the division created by the first optical element. The four segments of the beam are directed into an overlapping orientation. A lens is used to focus the beam in a target plane. The beam spot will have a square footprint with two sets of opposed straight edges. The intensity distribution will be substantially uniform across the spot permitting more uniform treatment of a workpiece.

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APPARATUS FOR CREATING A SQUARE OR RECTANGULAR LASER BEAM WITH A UNIFORM INTENSITY PROFILE

Technical Field

The subject invention relates to a device for converting a round beam having a gaussian-like intensity profile into a square beam with a uniform intensity profile. A square beam with a uniform intensity profile can be used to more uniformly treat a workpiece.

Background of the Invention

Lasers are presently being used for treating materials in a wide variety of applications. One area of interest includes medical applications where large regions of tissue are to be ablated. When treating tissue, it is desirable to deliver a relatively high power pulse in a short period of time (one the order of one millisecond or less). When the energy is delivered in a short period of time, diseased surface tissue can be ablated with minimal thermal damage to the underlying healthy tissue. Damage to the underlying tissue is minimized since most of the energy is utilized in vaporizing surface tissue. Because of the short time period, little energy is conducted to the underlying healthy tissue.

It has been found that to optimize performance, the radiant exposure (or fluence) at the surface must be at least three to four joules/cm^2. At this energy level and above, the tissue can be cleanly vaporized. For any given laser, this level of fluence can be obtained by controlling the spot size of a beam. Thus, for lower power lasers, smaller spot sizes are used to insure that desired fluence level is achieved. As higher power lasers have been introduced, the size of the spot can be increased, while maintaining the desired level of fluence. As can be appreciated, a larger spot size allows larger

areas of tissue to be treated in a shorter period of time.

Most laser are designed to generate an output which approximates the fundamental or TEM_{00} mode. This mode has a characteristic intensity distribution that is gaussian. As illustrated in Figure 1, a gaussian intensity distribution has a peak near the center and tails off rather rapidly towards the edges. While most lasers do not generate a pure fundamental mode beam, the intensity distribution of the output of most commercial medical lasers is similar to that shown in Figure 1. For the purposes of this specification and claims, the term gaussian or gaussian-like shall refer to any beam wherein the energy is high near the center axis and tends to decrease towards the radially outer portions thereof.

As lasers have increased in power allowing spot sizes to be increased, some problems have been encountered particularly when treating tissue with a beam having a gaussian intensity distribution. More specifically, if a gaussian beam is used to treat a spot on the tissue, the level of fluence obtained in the region near the center of the spot is much greater than the fluence generated near the radially outer edges of the spot. These variations result in uneven treatment in the region of the spot.

In order to overcome this problem, it has been suggested that a beam be provided with a more uniform intensity profile. Such an intensity profile is illustrated in Figure 2. Because of the rectangular appearance of this profile, this energy distribution is often referred to a "top hat" profile. The advantages of using a beam with a top hat profile for irradiating tissue was discussed in "Model Simulation of Biological Damage In Tissue Exposed to CO_2 Laser Irradiation," Gerstmann et. al, Optical Engineering,

Feb. 1993, Vol 32. No 2, Page 291. In the latter article, it was noted that the zone of thermal damage surrounding a treatment region could be reduced by using a beam having a top hat profile.

While the latter article discussed the advantages of using a beam with a top hat profile, there was no disclosure of the type of optical apparatus which could generate this form of output. One approach for achieving this goal was described in U.S. Patent No. 5,151,917, issued September 29, 1992, to Perilloux, assigned to the same assignee herein and incorporated by reference. The approach described in the latter patent relied on a diffractive optical element as part of the laser resonator to modify the output beam to present a top hat intensity profile.

While utilizing a beam having a uniform intensity profile addresses some of the problems of the prior art, difficulties still remain. More specifically, the proposals for a top hat beam have been limited to modifying the intensity profile across a conventional round beam. Thus, when viewed in three dimensions as in Figure 3, the prior proposed top hat intensity beam is still circular and propagates in the form of a cylinder.

A circular beam is suitable for treating small circular target regions. However, in practice, regions much larger than the spot size need to be treated. Therefore, the surgeon is required to juxtapose a plurality of contiguous spots to fully treat the region. In order to obtain the desired fluence level, circular spots had to be partially overlapped. Even with the most skilled hands, some of the regions would receive too much energy while other regions too little.

Accordingly, it is an object of the subject invention to overcome these problems by creating a beam which can be used to more uniformly treat a larger region of tissue.

Summary of the Invention

In accordance with this and other objects, the subject invention provides a method and apparatus for creating a beam having both a uniform intensity distribution and a square or rectangular cross-section. The uniform intensity distribution will allow for uniform treatment of tissue within the spot. More significantly, the square beam will facilitate treatment of larger areas of tissue because a large region can be more uniformly treated with a beam having at least two opposed straight edges.

The subject apparatus includes an optical means configured to convert a conventional round beam having a gaussian-like intensity profile into a beam having at least two opposed straight edges and a uniform intensity profile. The apparatus includes a pair of optical elements aligned with the center axis of the beam. The optical elements can consist of a pair of fold mirrors, prisms or diffractive optical elements (DOE).

The pair of optical elements function to divide the beam in half with each beam half having one straight side edge defined by the original centerline of the beam. The pair of optical elements also cause the two beam halves to overlap so that the two straight sides are pushed to the outer edges of the configured spot. The intensity of the radiation at the newly defined straight outer edges of the beam is equivalent to the intensity at the center of the original gaussian beam. The regions of both original

tails overlap in the center of the reconfigured spot so that the energy density in this region represents the sum of the energy in both tails. By combining the energy of the tails of the gaussian beam, the energy distribution along an axis extending between the straight side edges is substantially uniform.

As discussed below, a beam having two opposed straight edges and a uniform intensity distribution along the axis extending therebetween, can be very useful where the beam is being scanned over the work surface in a direction parallel to the straight edges. In this case, since the beam is being scanned, fluence in the direction of the scan can be controlled by the scan rate. A smooth treatment region along the edges perpendicular to the direction of the scan is achieved due to the straight edges of the beam.

For treating individual spots, it is desirable to create a beam having four straight edges in the form of either a rectangle or a square. To achieve this goal, a second pair of optical elements, similar to the first pair is provided. The second pair of optical elements is oriented in a manner to divide the beam along a centerline perpendicular to the division created by the first pair of optical elements. In combination, the two pairs of optical elements divide the beam into four quadrants and cause the quadrants to overlap to define a reconfigured beam spot. The edges of the quadrants define two pairs of opposed straight edges in the reconfigured beam. In addition, because the tails overlap in both axes, a uniform intensity distribution is created over the entire spot. A square or rectangular beam can be used to treat multiple contiguous spots without overlap providing for more uniform treatment.

In the preferred embodiment, a lens is used to collimate the overlapping sections of the beam. In this manner, the depth of field can be increased such that the beam diameter will remain relatively constant over a larger range .

Further objects and advantages of the subject invention will become apparent from the following detailed description taken in conjunction with the drawings in which:

Brief Description of the Drawings

Figure 1 is an illustration of the intensity distribution for a gaussian laser beam.

Figure 2 is an illustration of a laser beam having a rectangular or top hat intensity distribution.

Figure 3 is a three dimensional view of a round laser beam having a top hat intensity distribution.

Figure 4 is a schematic view illustrating the use of a prism and lens to reconfigure a round beam having a gaussian energy distribution into a beam having two straight side edges and a uniform intensity pattern along the axis extending therebetween.

Figure 5 is a diagram of the energy distribution which is achieved with the optical elements of Figure 4.

Figure 6 is an illustration of the scanning of a beam having an intensity distribution created by the optical elements of Figure 4.

Figure 7 is a schematic view illustrating the use of a folded mirror pair and a lens to create a beam having two straight side edges and a uniform intensity pattern along the axis extending therebetween.

Figure 8 is a schematic view illustrating the use of a diffractive optical element and a lens to create a beam having two straight side edges and a uniform intensity pattern along the axis extending therebetween.

Figure 9 is an illustration of a pair of prisms used to create a square beam with a uniform intensity profile.

Figure 10 is an illustration of a pair of fold mirrors used to create a square beam with a uniform intensity profile.

Figure 11 is an illustration of a four segment, composite prism used to create a square beam with a uniform intensity profile.

Figure 12 is an illustration of a four segment, composite fold mirror used to create a square beam with a uniform intensity profile.

Figure 13 is an illustration of a four segment, composite diffractive optical element used to create a square beam with a uniform intensity profile.

Figure 14 is a cross sectional view, taken along the line 14-14 of Figure 15, of a preferred form of apparatus utilizing two pairs of fold mirrors for converting a round laser beam having a gaussian intensity profile into a square beam with a uniform intensity profile.

Figure 15 is a perspective view of the apparatus of Figure 14.

Detailed Description of the Preferred Embodiments

Turning to Figure 4, there is illustrated a first embodiment of the subject invention. In Figure 4 (and in like figures), a round laser beam 10 having a gaussian-like intensity profile (indicated at 12) is shown propagating from the left to the right. The

beam is generated by a conventional laser 13. The beam 10 is directed to a target plane 15 via an optical delivery system.

In accordance with the subject invention, the delivery system includes a prism 20, having two facets, 22 and 24. Prism 20 functions to divide the beams in two halves (14 and 16) and redirect the halves on a converging path. Preferably, a lens 30 is located downstream from the prism 20 for recollimating and focusing the beam to a spot in the target plane.

The intensity distribution across the center of a beam which is created by the elements of Figure 4 is illustrated in Figure 5. The dotted lines 32 represent the respective contributions from the two halves of the original gaussian beam. As can be seen, what had been the right half 14 of the beam has been laterally shifted so that the straight centerline now defines the left edge 34 of the reconfigured beam. The tail from the right half 14 of the beam extends from the peak at the left edge 34 to a low intensity level at the right edge 36. Similarly, the left half 16 of the beam has been laterally shifted to the right, so that the original centerline of the gaussian beam now defines the straight, right edge 36 of the reconfigured beam. The tail from the left half 16 extends from the peak at the right edge to a low intensity level at the left edge.

As can be seen, the intensity levels at the two edges corresponds to the intensity peak at the center of the original gaussian beam. The intensity of the beam between the opposed side edges represents a combination of the intensity of the tails of the two halves. Significantly, as the intensity from tail 14 drops from left to right, the intensity of tail 16

increases. Conversely, as the intensity from tail 16 drops from right to left, the intensity of tail 14 increases. Thus, the total intensity (represented by the sum of the intensity of the two tails) taken along an axis extending between two straight edges remains relatively constant as indicated by the solid line 38 of Figure 5. As can be appreciated, the elements shown in Figure 4 can be used to create a beam spot with two straight side edges and a relatively uniform intensity pattern across the axis extending perpendicular to the side edges.

The subject approach will work best with any beam having something similar to a gaussian-like intensity distribution. Even with some beams that have an original profile significantly different from a gaussian distribution, some beneficial homogenizing effects on the intensity distribution might be achieved using the subject invention. The subject invention is intended to be applicable to any situation where the intensity profile of the reconfigured beam is more uniform than the intensity profile of the original beam.

As will be discussed below, the subject invention also includes an optical system for creating a square beam having two sets of opposed straight edges. However, a beam having only one set of opposed straight edges and a uniform intensity profile in the axis extending between the edges can also be very useful, particularly when the beam is being scanned.

Figure 6 illustrates how a beam having only one set of opposed straight edges might be beneficially used. More specifically, Figure 6 illustrates a beam spot 40 where the intensity distribution along the central horizontal axis A is the same that shown in Figure 5 (as indicated at the top of Figure 6).

However, since the distribution along the central vertical axis B has not been reconfigured, it remains gaussian as indicated at the right hand side of Figure 6. Thus, if spot 40 were to be used to treat tissue at a fixed position, the upper and lower regions of the spot (as viewed in Figure 6) would receive less fluence than the center region.

This problem can be overcome by scanning the beam along an axis parallel to the straight edges 34, 36 (arrow C). As can be appreciated, by scanning the beam at a fixed rate, the fluence supplied to the tissue along the vertical axis can be controlled. The faster the scan rate, the lower the fluence and vice versa. By scanning the beam, each portion of the tissue 42 in the path will be exposed to the same fluence along the scanning axis.

This control of the fluence by a time integration scheme can only be used to correct for non-uniformities of intensity distribution in the direction of the scan. If the energy distribution in a direction perpendicular to the scan direction (axis A) were gaussian, the level of fluence delivered to the tissue near the left and right edges of the beam would be much less than in the center of the spot. This problem is overcome by the subject invention since the intensity distribution across the horizontal axis is substantially uniform (as shown in the top of Figure 6). Thus, by reconfiguring the beam in only one axis, and scanning the beam in the other axis, substantially uniform treatment over the scanned area 42 can be easily achieved. For larger areas, the beam can be scanned along multiple, parallel and contiguous scan lines.

In addition to the prism 20 shown in Figure 4, variety of other optical elements can be used to split the beam into two halves. For example, and as

shown in Figure 7, a pair of mirrors 50 and 52 could be used to split and fold the beam 10 in a manner similar to the prism 20 of Figure 4. Lens 30 would be used to focus the halves of the beam into a spot having two opposed straight edges and a uniform intensity pattern along the axis extending between the side edges.

A similar result can be achieved using a diffractive optical element. A diffractive optical element (DOE) is similar to a grating having a number of steps at different heights. Light is diffracted off the edges of the steps creating an effect which is directly analogous to the refractive properties of a lens or prism. In the embodiment illustrated in Figure 8, a DOE 60 having two segments 62, 64 is used to replace prism 20 of Figure 4. The construction of a DOE to diffract light in a manner equivalent to a prism is well within the abilities of one skilled in the art and need not be discussed herein. As in the embodiment of Figure 4, lens 30 is used to focus the beam into a spot with two opposed straight edges.

As noted above, it is also an object of the subject invention to reconfigure a round, gaussian-like beam into a square or rectangular beam with a uniform intensity distribution in both axes. This result is achieved by including a second optical element for dividing the beam along a centerline perpendicular to the division made by the first optical element. When the four halves of the beam are recombined, a beam with two sets of opposed straight edges is produced.

Figure 9 illustrates this approach using a pair of identical prisms 70 and 72. Each prism includes two facets 74, 76, 78 and 80. As can be seen, the two prisms are oriented orthogonally with respect to each other. Prism 70 will function to divide the

beam in the horizontal axis in the same manner as prism 20 in Figure 4. Prism 72 will divide the beam along the vertical axis. A lens (not shown) can be used to focus the beam segments to create an intensity distribution as shown in Figure 5 in both the horizontal and vertical axes. The beam will have a square footprint with a substantially uniform intensity pattern throughout.

The advantage of a square beam with a uniform intensity pattern is that it can be used to uniformly treat individual spots without scanning. Of course, such a beam can also be scanned. Having a uniform intensity distribution in both axes would allow the beam to be scanned in any direction while maintaining uniform fluence levels.

As with the earlier embodiments, various other optical elements could be used to achieve this result. As shown in Figure 10, two pairs of fold mirrors 84 and 86 could be used. As can be seen, the center axes (88 and 90) of the fold mirrors as well as the mirror surfaces are orthogonally disposed. The two sets of fold mirrors will create a uniform intensity pattern in both axes.

In Figures 9 and 10, two separate optical elements are illustrated. Figures 11 to 13 illustrate embodiments where the two optical elements are combined into a single composite structure. More specifically, Figure 11 illustrates a prism 110 having four facets 112, 114, 116 and 118. The facets are formed in a pyramidal arrangement with two orthogonal axes 120 and 122. The four facets function to split the beam in quadrants. The overlapping quadrants can then be focused by a lens to create a square beam having a uniform intensity distribution.

Figure 12 illustrates a composite fold mirror 130 having four segments 132, 134, 136 and 138 arranged in a pyramidal configuration. Figure 13 illustrates a composite diffractive optical element 140 having four quadrants 142, 144, 146, and 148. A lens is used with either composite mirror 130 or DOE 140 to form a square beam having a uniform intensity distribution.

Figures 14 and 15 illustrate a preferred embodiment of the subject invention which has been fabricated and tested. This embodiment is intended to be used with a beam generated by a carbon dioxide laser such as the type manufactured by the assignee herein under the Ultrapulse trademark. The latter system includes a carbon dioxide laser which emits an output that is passed through optical elements to generate a beam having a generally circular cross section and a gaussian energy distribution. The beam is coupled into an articulated arm and then into a handpiece selected based upon the particular surgical procedure to be performed.

The embodiment shown in Figures 14 and 15 includes a housing 150 which is intended to be interconnected between the delivery end of the articulated arm 152 and the handpiece (not shown). Housing 150 includes a coupler 154 for connection to the articulated arm. The beam enters the housing and into a channel 160. The beam is then reflected off two sets of fold mirrors having a configuration similar to that shown in Figure 10.

The first pair of fold mirrors 162 is mounted at one end of the housing. Fold mirrors 162 function to divide the beam in half and redirect the beam to a second pair of fold mirrors 164. (Only one mirror in each pair 162, 164 is seen in the cross-sectional view of Figure 14.) Fold mirrors 164 are oriented

along an axis perpendicular to fold mirrors 162 and also divide the beam in half. The beam, which now consists of four converging segments, exits housing 150 through coupler 170. A lens (not shown) in the handpiece could be used to focus the beam into a form having a square configuration and a uniform intensity pattern.

In the particular prototype illustrated in Figures 14 and 15, a generally round, gaussian-type beam, having a diameter of about 6mm, was supplied to the input coupler 154. The combination of the two sets of fold mirrors 162 and 164 created a square beam spot, 3mm by 3mm, with a substantially uniform intensity pattern throughout. The beam generated by the apparatus of Figures 14 and 15 was used to ablate tissue in dermatological procedures without any additional focusing elements.

The subject invention could be used in a variety of other medical procedures where large area ablation is desired. The subject invention could also be utilized in non-medical applications such as material processing where uniform treatment of a workpiece is desired.

While the subject invention has been described with reference to the preferred embodiments, various changes and modifications could be made therein, by one skilled in the art, without varying from the scope and spirit of the subject invention as defined by the appended claims.

CLAIMS

1. An apparatus for modifying the intensity distribution of a laser beam having a gaussian intensity pattern:

a first optical means defined by a pair of planar angled fold mirrors for dividing the beam into two halves and for causing the halves to overlap; and

means for focusing the beam halves in a manner to create a beam spot, said beam spot having two opposed straight boundaries and wherein the distribution of intensity of beam is substantially constant along the axis extending between the opposed boundaries.

2. An apparatus as recited in claim 1 further including a second optical means for dividing the beam into two halves along a centerline perpendicular to a centerline created by the first optical means and wherein all of said halves overlap to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

3. An apparatus for modifying the intensity distribution of a laser beam having a gauss ian-like intensity pattern:

a first planar fold mirror aligned with a first half of the beam; and

a second planar fold mirror aligned with the remaining half of the beam, said fold mirrors causing the beam halves to overlap and form a beam spot, said beam spot having two opposed straight boundaries and wherein the

distribution of intensity of the beam is substantially constant along the axis extending between the opposed boundaries.

4. An apparatus as recited in claim 3 further including third and forth planar fold mirrors for dividing the beam into two other halves along a centerline perpendicular to a centerline created by the first and second fold mirrors, with all of said halves overlapping to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

5. An apparatus as recited in claim 4 further including a lens for focusing the overlapping halves of the beam.

6. An apparatus for treating a workpiece comprising:

means for generating a laser beam having a gaussian-like intensity pattern; and

means for delivering the beam to the workpiece, said delivery means including a first optical means defined by a pair of planar, angled fold mirrors for dividing the beam into two halves and causing the halves to overlap to create a beam spot, said beam spot having two opposed straight boundaries and wherein the distribution of intensity of the beam is substantially constant along the axis extending between the opposed boundaries.

7. An apparatus as recited in claim 6 further including a second optical means defined by a pair of planar, angled fold mirrors for dividing the beam

into two halves along a centerline perpendicular to a centerline created by the first optical means and wherein all of said halves overlap to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

8. An apparatus as recited in claim 7 further including a lens for focusing the overlapping halves of the beam.

9. A method of treating tissue with a laser beam comprising the steps of:

forming a beam spot having a generally square cross section and a uniform intensity distribution throughout the spot; and

directing the beam spot to the tissue to be treated for a predetermined time period to uniformly treat the tissue within the region of the spot.

10. A method of treating tissue as recited in claim 28 wherein the laser beam is originally round and has a gaussian intensity distribution and wherein said step of forming the beam spot includes:

dividing the beam into four quadrants along two perpendicular centerline and causing said quadrants to overlap; and

focusing the beam quadrants in a manner to create a rectangular beam spot

11. An apparatus for modifying the intensity distribution of a laser beam having a gaussian intensity pattern:

a first optical means defined by a diffractive optical element for dividing the beam into two halves and for causing the halves to overlap; and

means for focusing the beam halves in a manner to create a beam spot, said beam spot having two opposed straight boundaries and wherein the distribution of intensity of beam is substantially constant along the axis extending between the opposed boundaries.

12. An apparatus as recited in claim 11 further including a second optical means defined by a diffractive optical element for dividing the beam into two halves along a centerline perpendicular to a centerline created by the first optical means and wherein all of said halves overlap to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

13. An apparatus for modifying the intensity distribution of a laser beam having a gaussian intensity pattern comprising:

optical means defined by a composite diffractive optical element for dividing the beam into four quadrants along two perpendicular centerlines and causing said quadrants to overlap; and

means for focusing the beam quadrants in a manner to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

14. An apparatus for treating a workpiece comprising:

means for generating a laser beam having a gaussian-like intensity pattern; and

means for delivering the beam to the workpiece, said delivery means including a first optical means defined by a diffractive optical element for dividing the beam into two halves and causing the halves to overlap to create a beam spot, said beam spot having two opposed straight boundaries and wherein the distribution of intensity of the beam is substantially constant along the axis extending between the opposed boundaries.

15. An apparatus as recited in claim 14 further including a second optical means defined by a diffractive optical element for dividing the beam into two halves along a centerline perpendicular to a centerline created by the first optical means and wherein all of said halves overlap to create a rectangular beam spot having two pairs of opposed straight boundaries wherein the intensity distribution throughout the spot is substantially uniform.

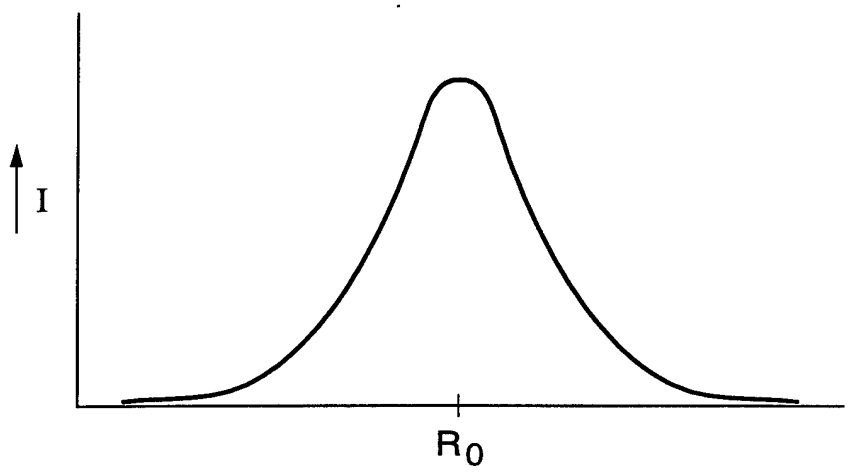

FIG. 1

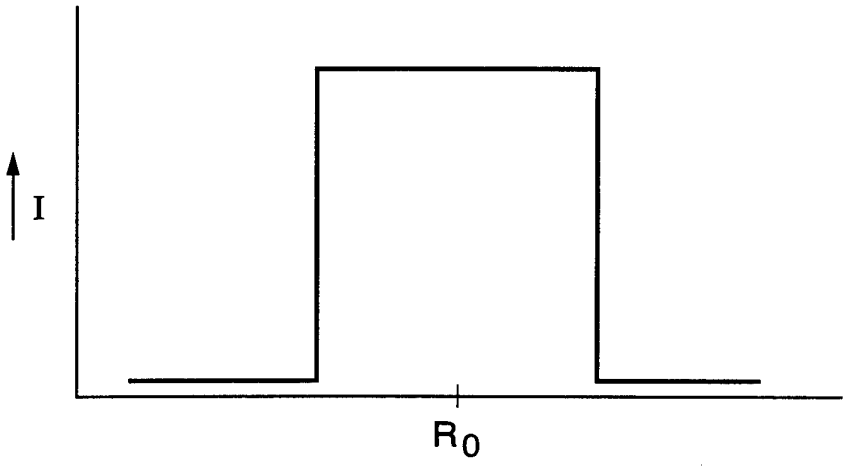

FIG. 2

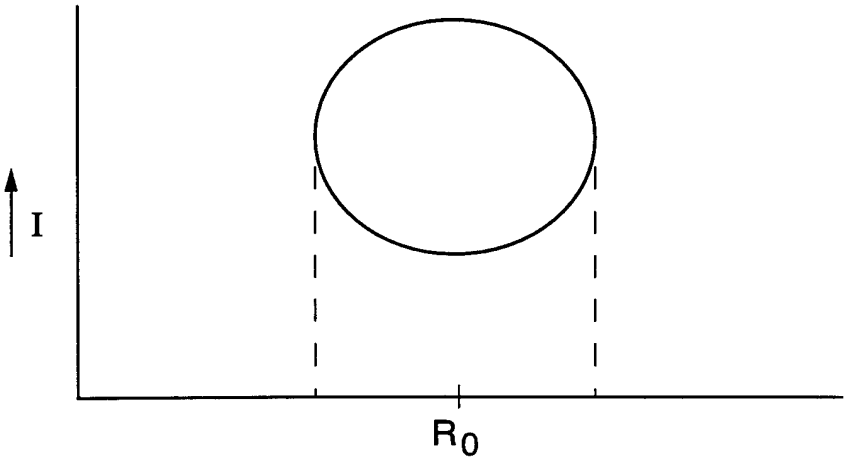

FIG. 3

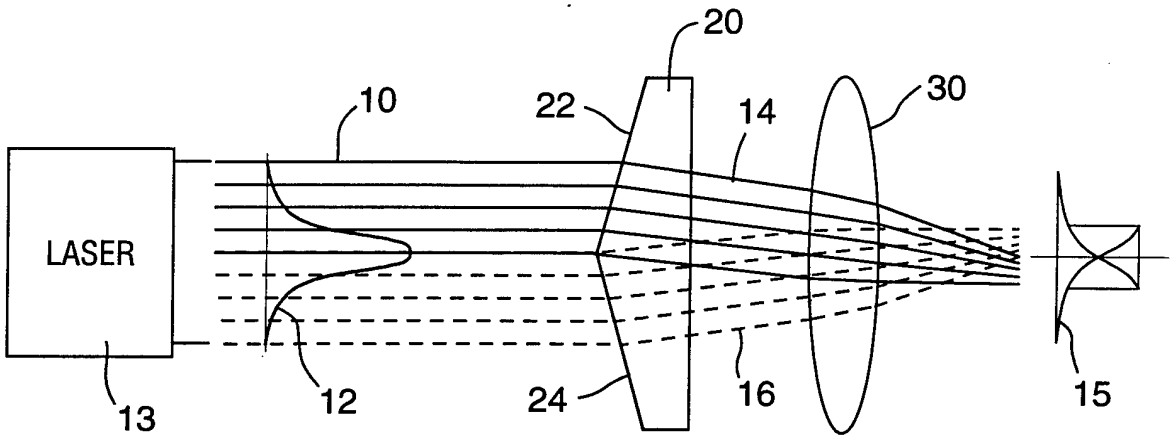

FIG. 4

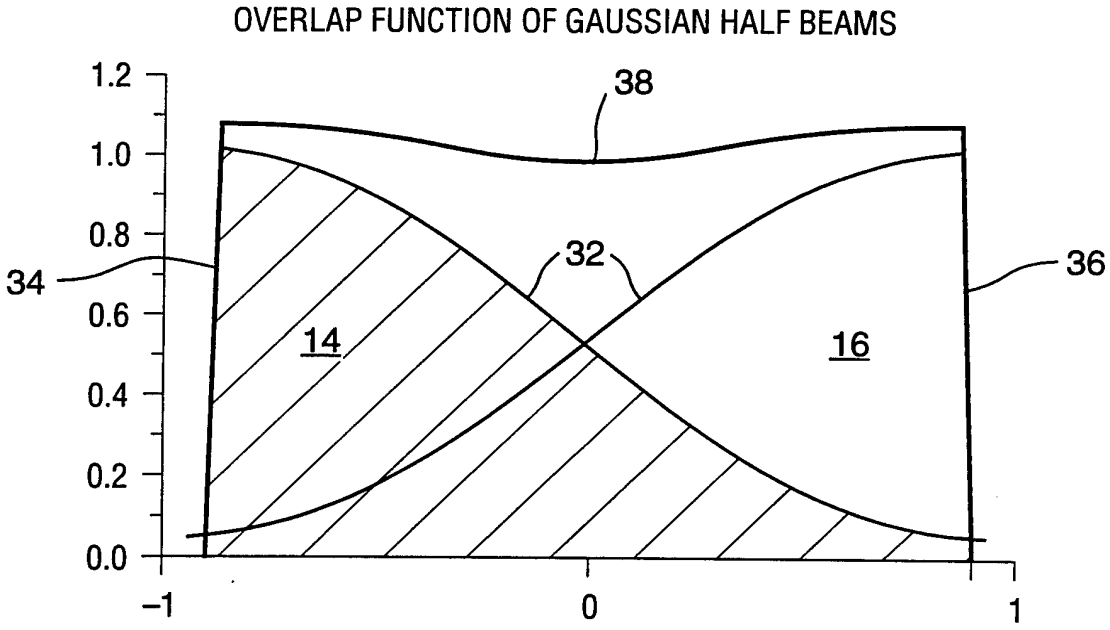

FIG. 5

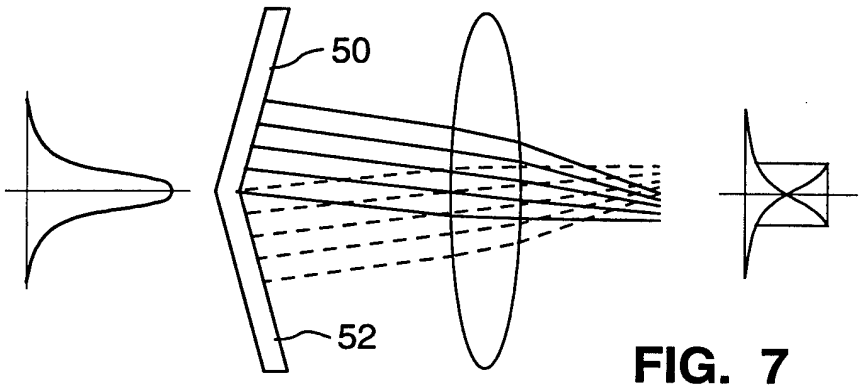

FIG. 7

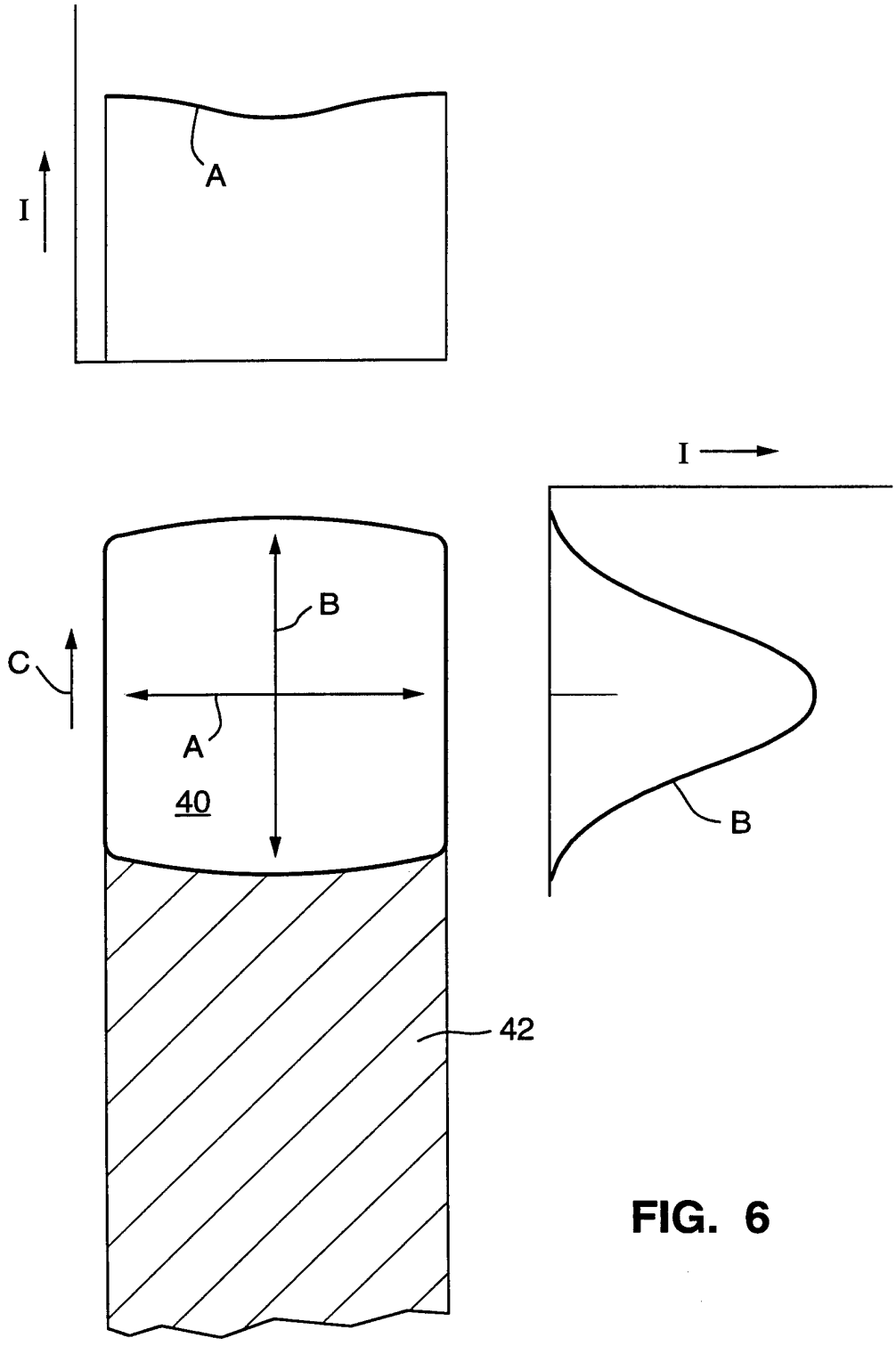

FIG. 6

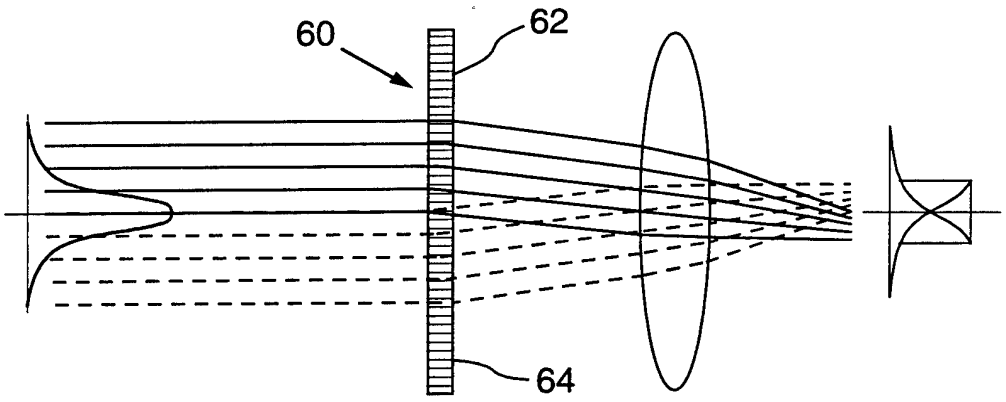

FIG. 8

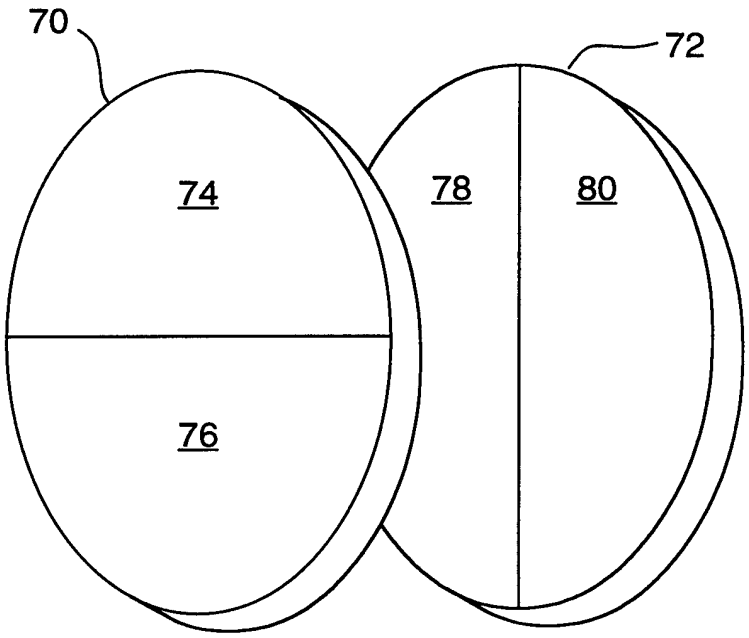

FIG. 9

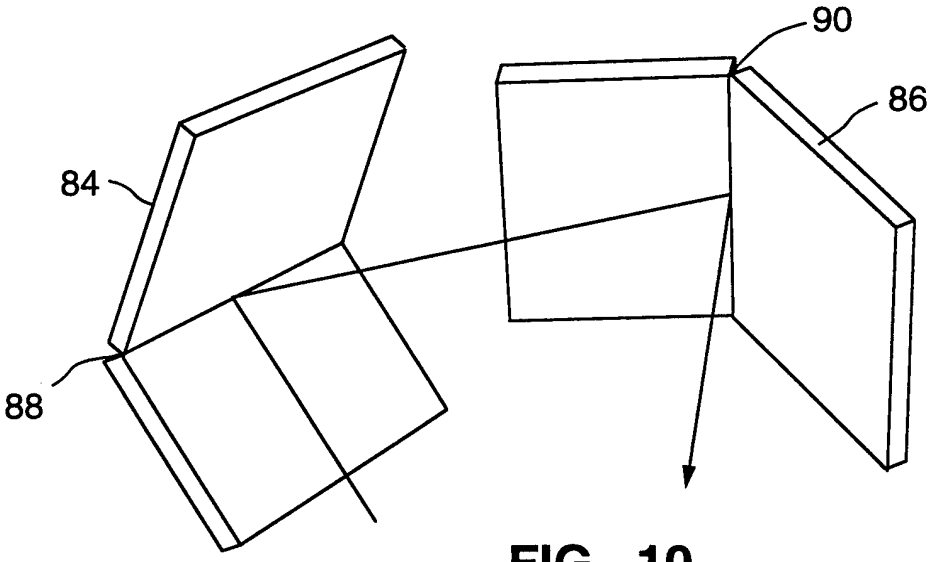

FIG. 10

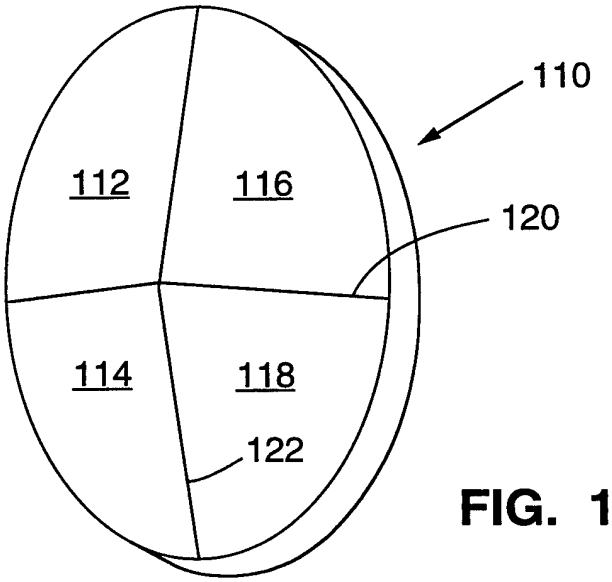

FIG. 11

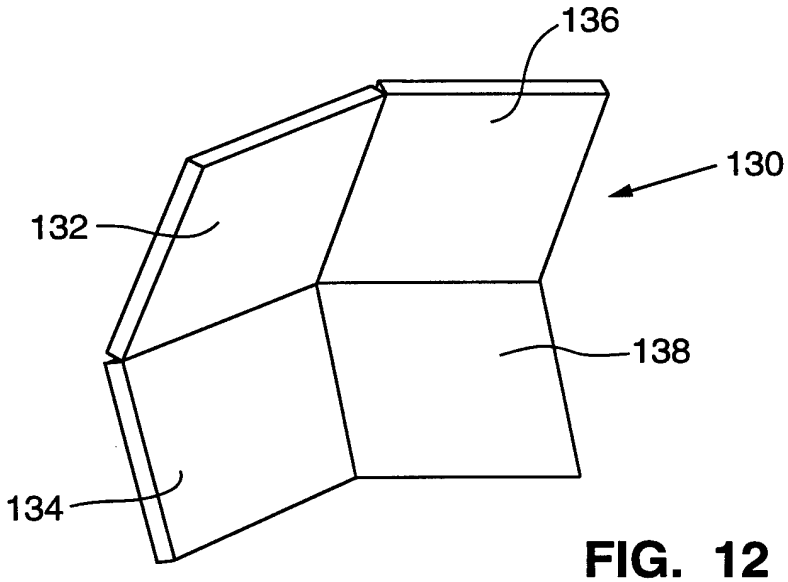

FIG. 12

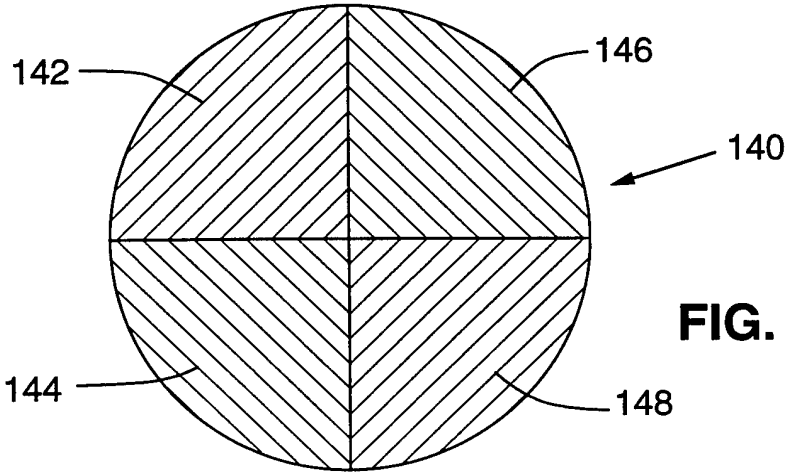

FIG. 13

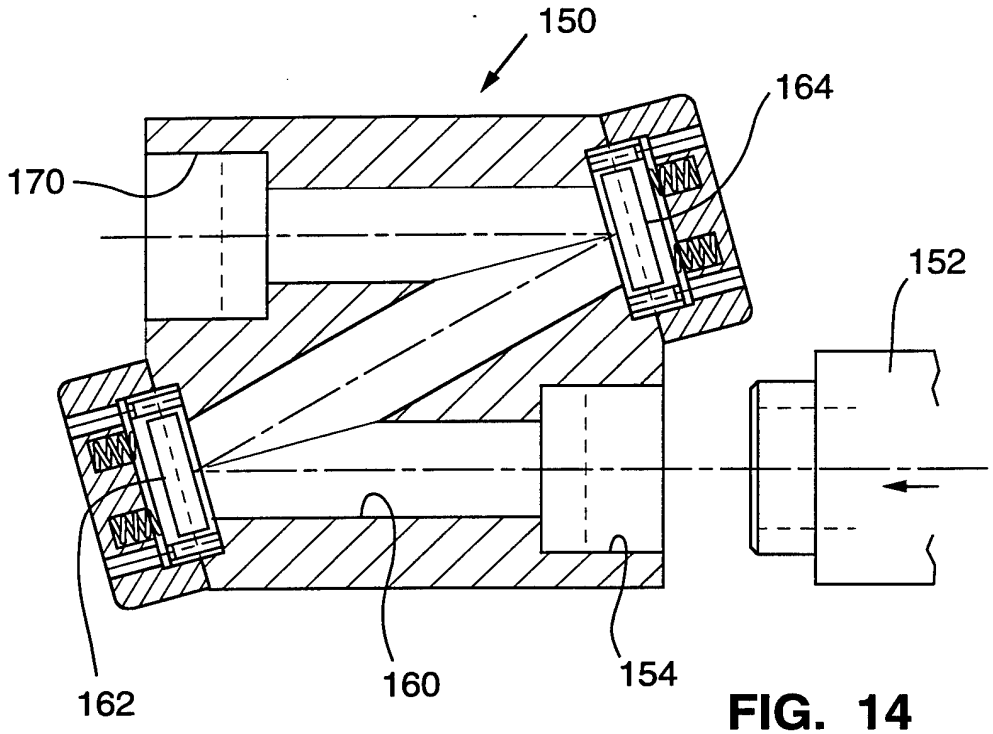

FIG. 14

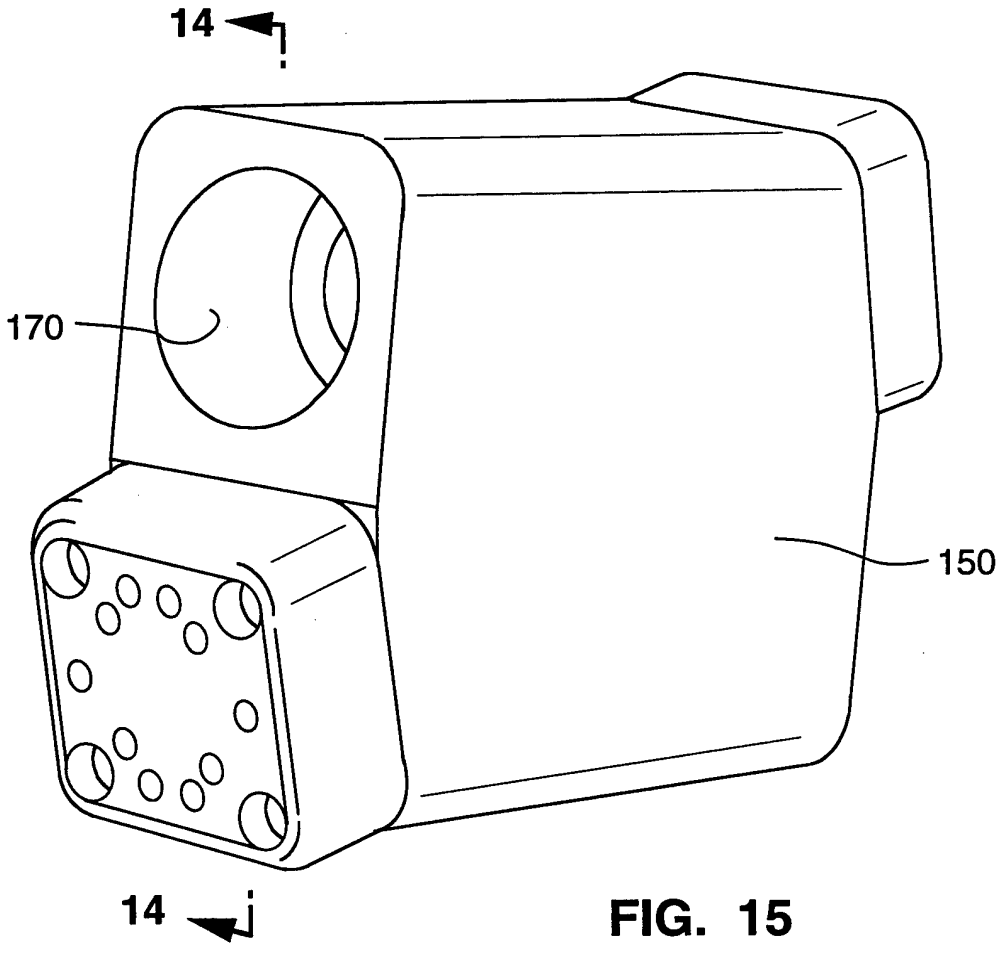

FIG. 15

INTERNATIONAL SEARCH REPORT

Intern ıal Application No
PCT/US 95/00115

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B27/00 H01S3/00 B23K26/06 A61B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B H01S B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	OPTICS COMMUNICATIONS, vol.57, no.3, 1 March 1986, AMSTERDAM NL pages 161 - 165 GIRARDEAU-MONTAUT ET AL 'Optical Device Analysis for Uniform Intensity Irradiation from a High Energy Gaussian La er Beam'	1-4,6,7
A	see the whole document ---	9-15
X	REVUE DE PHYSIQUE APPLIQUEE, vol.24, no.12, December 1989, PARIS FR pages 1111 - 1118 LI JUNCHANG ET AL 'Etude Théorique d'un Dispositif Permettant de Condenser un Faisceau Laser Gaussien en une Tache Carrée de Dimension Variable avec une Répartition d'Energie Homogène'	1-8
A	see the whole document ---	9-15

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 April 1995	- 3. 05. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Ward, S

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INTERNATIONAL SEARCH REPORT

Interr ıal Application No
PCT/US 95/00115

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JOURNAL OF OPTICS, vol.21, no.2, March 1990, PARIS FR pages 51 - 61 MERLIN ET AL 'Modification par Recombinaison de Faisceaux de l'Éclairement Délivré par une Source Laser de Puissance: Étude Théorique et Expérimentale'	1,3,6
A	see the whole document	5,8,9, 11,13,14

X	APPLIED OPTICS., vol.29, no.20, April 1990, NEW YORK US pages 1736 - 1744 IWASAKI ET AL 'Square and Uniform Laser Output Device: Theory and Applications' see the whole document	9

A	SU,A,1 697 041 (AS USSR SPEC TOOLS DES BUR/ SAMARA AVIATION INST) 7 December 1991 see abstract; figures	1,3,6,9, 11,13,14

A	SU,A,1 697 042 (AS USSR SPEC TOOLS DES BUR/ SAMARA AVIATION INST) 7 December 1991 see abstract; figures	1,3,6,9, 11,13,14

A	EP,A,0 213 471 (TOSHIBA) 11 March 1987 see the whole document	1,3,6,9, 11,13,14

A	JOURNAL OF OPTICS, vol.18, no.2, March 1987, PARIS FR pages 73 - 80 JUN-CHANG LI 'Etude Théorique d'un Dispositif Optique et de ses Variantes pour Uniformiser l'Eclairement d'un Faisceau Gaussien TEMoo' see the whole document	1-15

A	OPTICS COMMUNICATIONS, vol.48, no.1, 1 November 1983, AMSTERDAM NL pages 44 - 46 KAWAMURA ET AL 'A Simple Optical Device for Generating Square Flat-Top Intensity Irradiation From a Gaussian Laser Beam' see the whole document	1-4,6,7, 9-15
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1 A	GB,A,2 220 502 (EXITECH) 10 January 1990 see the whole document	1-15

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Intern ...al Application No
PCT/US 95/00115

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SU-A-1697041	07-12-91	NONE	
SU-A-1697042		NONE	
EP-A-0213471	11-03-87	JP-A- 62037350 US-A- 4692583	18-02-87 08-09-87
GB-A-2220502	10-01-90	NONE	